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ABSTRACT

This paper addresses the problem of an inadequate science teaching approach at a time when students need to be familiar with, and be able to understand, global problems and personal problems delving into complex, interrelated issues based on the science of a living universe. This report focuses on research about the problems in science education, the dilemma today and for the future in science education, program attempts in science education, and what educators can do to enhance science curricula. Chapters cover: (1) an introduction to the problem under study; (2) a literature review; (3) a brief overview of implemented programs emphasizing strengths and wesknesses; (4) positive approaches and recommendations to science education for curriculum enhancement; and (5) summary and conclusions. An appendix includes two model science activities: "Making Rounds with Dr. Semmelweis," and "The Problem of Gierer and Schramm." A list of 37 references is included. (CW)

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INTERDISCIPLINARY APPROACHES TO SCIENCE EDUCATION

Jane McGinnis

Science education goals relate to the needs of society... the facts and skills a person needs to deal with the environmental and energy issues which affect society at large... a knowledge of issues and how science relates to them... and a sense of custodianship to protect and preserve the natural world. (Kahl and Harms N.C. Project Synthesis: Purpose, Organization and Procedures "What Research Says to the Science Teacher," Vol. 3 Washington, D. C.: National Science Teachers Association, 1981).

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We are architects of fate

Working in these walls of time

Some with massive deeds and great

Some with ornaments of rhyme

Longfellow
The Builders

Scientific research is not itself a science, it is still an art or craft

W. H. George

CHAPTER I

Introduction

In his Eco-Spasm Report, Alvin Toffler states:

> A closer look (at the economic situation) reveals that, like generals, economists are busy fighting the last war. Their stabilizer and tools seem increasingly like some cob-webbed, economic version of the Maginot Line - a mighty fortress with guns pointing in irrelevant directions. For all their defenses are premised on the perpetuation of industrial society, not its transformation into something strange, new, and radically different. Nothing in the history of traditional industrial societies has prepared them for today's high-speed world of instant communication, Eurodollars, petro-dollars, multinational corporations and ganglia-like international bank consortia.[1]

These words are indicative of the plague sweeping our country as well as the world. The plague is that of an unhurried satisfaction with the present and only a small portion of concern for the future. These changes are so abruptly confronting our society that we are not ready or equipped to handle them.

Many recent journals and research articles shed light about the goals and methods of contemporary science education in all realms and levels. The crisis in science education has all too frequently been

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[1]Alvin Toffler, The Eco-Spasm Report (New York: Bantam Books, 1975), pp. 4-5.

attributed to external factors: fiscal, political, sociological. Now, we as entrepreneurs in education, must turn to the science enterprise itself. A primary concern should be that society is settling into a milieu where both the educated and uneducated have "abrogated their science-related decision making to a 'priestly elite'."[2] There continues to exist a paradox because the quality and quantity of science education have declined; the major concerns in science seem to have increased. The public will have almost no exposure to science-related information notwithstanding what they see on television or read in newspapers and magazines. And although a great deal of science reporting is high quality, the reporting has limitations in that this is a less than adequate way to deal with or provide a thorough grounding in science. So we see the dilemma of a race to be run on a track of stones and potholes. We as educators must ask ~~not~~ what truly is the most erudite way to pave our track for that future struggle we inevitably must face. This writer now intends to address the issue of an inadequate science teaching approach to the science curriculum, and

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[2]John E. Schafer, "Crisis in Science Education: A Need for Introspection", Journal of Research in Science Teaching, vol. 20, No. 6, 1983, pp. 593-594.

approaches to confront the science conflicts waiting around the bend.

I. The Problem

Statement of the Problem

The focus of this discourse will be directed on the following questions:

I What does research state about the problems in science education?

II What is the dilemma today and for the future in science education?

III What did programs attempt to do and what did they fail to address in the area of science education?

IV What can educators do to enhance the science curriculum and make it more viable for our future generations?

Significance of the Problem

The significance of the problem of the dilemma in science education lies in the future generation we as educators are encouraging to develop. Our future global problems must lie with today's students. These

students need to be familiar and able to understand global problems and personal problems delving into complex, interrelated issues based on the science of a living universe.

Close to a century ago, John Dewey was sincerely concerned about teaching practices predominant in America. The elitism, irrelevance and trivality of curricula in a majority of schools, as well as rote memorization and mechanical routine at the expense of inquiry and creativity, concerned this educator. Dewey propounded science as being the most potent force in the modern world.[3] Today this statement shines even more light on a path for a successful world. We face natural disasters: floods, drought, food shortages, etc., as well as personal disasters: debilitating diseases, stress in an ever changing world, sustaining our life style and facing problems of a fast-paced changing world. We must be prepared to make intelligent decisions and learn to appreciate life at its fullest. Plato stated:

> He who would be truly initiated should pass from the concrete to the abstract, from the individual to the universal, from the universal

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[3]Ibid

to the universe of truth and beauty.[4]

The writer intends to develop a case for changes and modifications with our present science curriculum framework. The maxim, "an enlightened man is a wise man" holdstrue for science education and students of tomorrow.

II. Procedures Used

Literature

Methods of research designed to address the questions concerning the dilemma in science education remain primarily within the realm of periodicals dating from 1970-1985 as well as science relevant texts.

Text examination, direct observation of a variety of programs and materials (cognitive levels matching program, 1984, PSSC, BSCS) enhanced the library research.

Limitations

This study was limited to review of literature between 1970-1984. Limitations involve a lack of direct research and observation of science methods being facilitated today.

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[4]Dialogues of Plato, Washington Square Press, New York, 1950, p. 216.

CHAPTER II

Review of the Literature

Bill G. Aldrdige, Executive Director of National Science Teachers Association, comments in Education Week:

> There is an overwhelming evidence that we are producing a citizenry that is scientifically and tehnically illiterate. The knowledge gap between scientists and engineers and the general public has widened most in this time when the public has most needed knowledge to make important personal and societal decisions. What are the most serious causes of this failure in our educational enterprises?[5]

Course content of high school physics, chemistry, and biology, primarily offsprings of curricular reforms of early 1960's, focus on pure science. Aldridge continues to expound:

> The courses focus on pure science and are largely devoid of practical applications, technology, or the relevancy of science to society problems such as acid rain, nuclear wastes and disposal of hazardous materials, or improper nutrition. These conditions do not prepare people to enter the myriad of nonscience occupations that require technological knowledge; nor do they open the way toward careers in math, science, and engineering for all those who have the ability to succeed.[6]

We have entered a new era, that of technology. We

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[5] Bill G. Aldridge, Executive Director, NSTA, Why a Crisis in Science Education?" Education Week, Nov. 14, 1984.

[6] Ibid

will be heading in different and varied directions with technology in the future. Students' needs and knowledge must be fostered to complement this fast paced world. Science teaching hence must address these needs.

Penick and Yager adamantly agree with Michael Leyden in The Science Teacher. They concur:

> Prison! We should be preparing our students to do time in prison. Leyden points out that only one percent of 10th grade biology students will become scientists, while more than that will end up in penitentiaries.
>
> With most students somewhere between future prisoners and future scientists, the science curriculum must provide for the majority by preparing science literate citizens for the world of tomorrow. Science literate citizens have an understanding of the nature of science and are able to use it in their daily lives. They appreciate basic research, understand the role of science and development of technology, and feel confident they can use new technology.[7]

Our schools, for the most part, lack the initiative, curriculum, and in many instances qualified teachers to do this job. Frances S. Vandervoort, in an astute article, "What Would John Dewey Say About Science Teaching Today?", fired that inquiry and decision making are mere shadows of today's learning process. Mr. Vandervoort, as well as other educators, see the need to educate the

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[7]John E. Penick and Robert E. Yager, "Science", Educational Leadership, Sept. 1984, p. 93.

general population to understand significances of today's scientific dilemmas. Citizens must be able to take intelligent stands on issues such as biomedical engineering, hazardous wastes, nuclear fuel. And today more than any other discipline, science is intertwined with social, political, and economic fabric of the nation.

Vandervoort believes our present approach to science teaching is frequently inadequate and inappropriate. Students learn through instruction, means of listening, reading, and memorizing; inquiry is seldom used. Most science courses neglect the effects of science and technology on society and a paucity of attention is given to developing an awareness of scientific careers.

Ms. Vandervoort states:

> Project synthesis, the recent study of status of pre-collegiate science education in the United States, shows that many of Dewey's criticisms hold true today. A summary of that reports that: 1) The activities which inaugurate and sustain the teaching of scientific inquiry are conspicuously absent in most schools. 2)(Teaching) goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision-making, are largely ignored. 3) Science education has accepted very little responsibility for education in

> the STS (science, technology, and society) domain.[8]

In these statements we see a great deal of what is wrong with science education today. We see why the average American believes that science is something done only in a laboratory or that a theory is little more than simplistic conjecture. To return to Dewey, we know that he was convinced that a scientific approach would improve education. Dewey developed his laboratory school of the University of Chicago in that he sought to use children's natural activity and curiosity in ways that would enable them to handle activity and curiosity in ways that would enable them to handle problems in an intelligent way. The teacher would then serve as a Taoist helper to lead a child from his own fund of voluminous experiences to the proper information and skills needed for addressing the problems of life. Primarily, Dewey advocated the use of inquiry which he viewed as the instrument of science. In support of Dewey's pragmatism and espousal of the experiential, we turn to William James who stated in the famous essay, "The Will to Believe":

> ..... in which there is no valid intellectual reason for choosing between

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[8]Frances S. Vandervoort, "What Would John Dewey Say About Science Teaching Today?" The American Biology Teacher, vol. 45, No. 1, Jan. 1983, pp. 38-41.

> conflicting propositions, there is a right to believe in that alternative which will have the most satisfactory consequences as a result of our belief, in the long run, and insofar as we can foresee the consequences.[9]

Man needs to look at science as a tool for wise choices in a radically changing and sometimes treacherous world. This changing balance in our world of machinations will affect both society and education in the next 20 years. A balanced education for the next century must be based on knowledge, values, and skills. We must teach students to reach deep within themselves to discover answers to issues in our world. Hence, we must develop a new science education for the 21st century. Fletcher Watson, in his article, "On the Drawing Board A 21st Century Curriculum", seeks a novel and humane program which will require time and effort to reach a consensus with the creation and adoption of instructional materials and procedures taking much longer. The NSTA (National Science Teachers Association) Horizon Committee offer the following propositions:

> Science is the persistent effort to explore the material universe and to create order by testable explanations of observed objects and events. The premises that underlie science have often been influenced by artistic, social, or political thought. To ensure the quality of life, therefore, a balanced education must integrate schooling in science, language, mathematics, social sciences, and humanities.

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[9]William James, Pragmatism and Other Essays, (New York: Washington Square Press, 1963), p. XIII.

Applied science, the interface between science and society, is a necessary component of science education. Effective science education should produce scientists and informed citizens prepared to deal responsibly with social issues related to science and technology. We live in an age when learning about science is necessary for becoming an informed citizen. People differ in their abilities, interests, and prior experiences. As a consequence, individuals learn at various rates and, over the same period of time, reach different levels of accomplishment. Teachers have been and will continue to be the single most important part of schooling and science education. Students need teachers to guide and assist them as they begin to learn science, but the nature of the need changes as students and tasks change.[10]

Glen Hass in an article, "Eighty Years of Curriculum Theory", addresses the historical aspect of the four bases of curriculum planning and links their development to myraid views of human nature, each of which has been the focus of study within this century. These views include rational economic man, social man, and self-

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[10]Fletcher Watson, "On the Drawing Board, A 21st Century Curriculum", The Science Teacher, March 1983, pp. 62-63.

actualizing man. Curriculum planners committed to one of these views have often tended to neglect or reject the others.[11] Now because we are aware today that all human behavior is a product of complex interacting forces, a "complex person" perspective is needed. A multidimensional approach to curriculum is essential.

Learners need to be introduced to new situations from everyday life in which the learner can indicate the likely effect of technology on such situations. Characteristics, limitations, and capabilities of modern technology will be used by the learned in determining the effect. Students should be given the opportunity to assess the future effect and value to persons.

The interdisciplinary approach appears continuously on the scene. After all, life itself is a tapestry woven of multicolored threads. The curriculum itself should be so inclusive in various facets. Penick and Yager state:

> At present, program planners in several countries are developing and implementing new curricula that reflect not only what we know about the learner and the nature of science, but also what we know about society. They recognize that science without societal applications means little

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[11]Hass, Glen, Curriculum Design, 1984, p. 23.

> to citizens alike. These programs incorporate the discovery of scientific ideas with career awareness and preparation as well as participation in decisions about learning and the usefulness of science applications in particular situations. Students use this learning by taking action to solve community concerns and problems.

An example of this trend -- the preparation of science literate citizens -- is the Science Technology - Society (STS) which presents the structure of science in relation to society spotlighting the troublesome elements, particularly the most subjective and value laden. [12]

So now we have the problems and framework for an applicable science curriculum. The remainder of this paper is intended to deal with the applicability of the curriculum and proposed models.

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[12] Ibid (b) Penick and Yager

Organization of Remainder of Treatise

The remainder of this paper will be as follows:

Chapter II consists of a review of literature concerning a crisis in science addressing the dilemma in science education today.

Chapter III contains a brief overview of programs implemented, past and present -- emphasizing strengths and weaknesses.

Chapter IV consists of positive approaches to and recommendations to science education for enhancement within the curricular framework for future generations.

Chapter V consists of summary conclusions and brief recommendations.

CHAPTER III

Programs and Possibilities - A Brief Overview

We turn now to address the more recent curriculum models, their problems and inadequacies. The alphabet courses of the 60's and 70's (CBA, CHEMS, BSCS,ISSC , ESCP) did improve the teaching of science in the secondary schools. However, much of the content of these courses was written to conform to the ideas and needs of single science enthusiasts. They succinctly ignore interdisciplinary approaches needed today.[13] Frequently, a majority of the students cannot use the teaching materials efficiently because modern issues in science are omitted. Teaching machines and other learning devices are left out. These courses ignore needs of general students and development of a future citizenry. Much of the material addressed wallows in an inundating tide of details -- details which have little or no bearing on the present problems of living. J. Lloyd Trump in Secondary School Curriculum Improvement advocates a multidisciplinary and problem solving capability. Science should become an interwoven thread

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[13]Carter, Jack, "The Human Sciences Program and the Future", The American Biology Teacher, vol. 44, No. 7, Oct. 1982, p. 427.

which runs through all education and thus becomes available to all students. [14]

Ralph Tyler, in retrospect of progress of American Schools, noted places where students have become involved in local community issues. Other savants have elucidated the point how the wholesale adoption of Western technological ways into developing countries raises tremendous social and political problems. Teacher inservice and education are of prime importance in these areas.

Lucas, in "Science Curriculum Objectives for the Future", states:

> Even in highly developed technological societies, many issues in which students can become involved have no simple solution which can be found in a scientific text or laboratory. Shumacher's penetrating analysis of large corporations and the question of ownership, for example, was undertaken from a number of quite different viewpoints. It would be instructive for high school science students to take a similarly multifaceted look at an environmental problem such as pollution of a local creek by waste from a large factory. Although they would probably not solve very many problems, the experiences gained in grappling with problems of such significance would be of tremendous value to them in future years.[15]

Indeed, science must become an interwoven thread

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[14] J. Lloyd Trump and Delmas F. Miller, Secondary School Curriculum Improvement (Boston: Allyn & Bacon, Inc.), 1979, pp. 216-217.

[15] Lucas, Keith B., "Science Curriculum Objectives for the Future", Science Education 65 (3): 317-322, 1981.

which runs through all education and thus becomes available to all students. And interdisciplinary approaches to learning address this dilemma in science education. Hence, science (along with math) will serve as a basis for the general strata curriculum to produce a more informed public, able to make critical decisions in a future hinging on the brink of disaster or intriguing fulfillment.

In 1972, the Center for Unified Science Education was set forth by a grant for FUSE (Federation for Unified Science Education) to be located at Ohio State University (now at Capital University). The FUSE concept utilizes many and varied techniques for implementing a unified science concept. The FUSE program utilizes a modular unit approach. The guidelines are as follows:

1) Be organized around a theme that is either (a) a concept that permeates all sciences (b) a process of science (c) a natural phenomenon or (d) a problem;

2) Incorporate learning projects from many of the specialized sciences;

3) Use a few objectives that are clearly stated in learners' terms;

4) Substantiate learning activities for four to eight weeks of school time;

5) Use a variety of learning models;

6) Be primarily self-contained but be an integral part of the local science program;

7) Use an end of unit test based on achievement of unit objectives and containing only a few items of recall nature;

8) Advocate a format that will achieve a philosophy of continuing evaluation;

9) Hold opportunities for students to choose some of what they learn and how they learn it;

10) Utilize available equipment and materials;

11) Use a rationale that is addressed to both learners and teachers and that describes reasons for the unit's importance, interest, and so on;

12) Use many opportunities for learners to self check their progress, interest, and so on;

13) Use a short description of teacher's role in the unit;

14) Delineate sources used in the unit;

15) Additional lists of materials and resources required in the unit are to be added;

16) Be developed around an adequate framework of number of hours of work required to implement.[16]

Other approaches to today's science include mini-courses, environmental approaches, inquiry teaching.

Members of the NSTA Horizons Committee propose a long-term effort by science educators to change the curriculum. The essential course might include a clear set of goals -- that could serve all state and local plans and guide instruction throughout 12-14

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[16]Trump and Miller, Secondary School Curriculum Improvement, pp. 221-222.

years of formal schooling. This type of curriculum might include:

1) The development of a familiarity with the natural world;

2) An understanding that humans can create testable hypothesis about that world;

3) An awareness of the many factors influencing the transfer of scientific knowledge through technology to society;

4) Sympathy for the efforts of scientists;

5) Opportunities for those having special talents or special limitations;

6) Attention to the role of machines on expediting learning.[17]

Recent emphasis has been placed on even higher standards including stricter graduation requirements in the sciences. Hence, we have impetus for new directions and decisions for effective science programs for the 80's. The search for excellence in science education incited educators to scrutinize curriculum, teaching methods and the role of technology in science programs. The National Science Board commissioned a special study group which has seen a need for the development of school science programs that are appropriate for all students, which strengthen the traditional programs

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[17]Watson, "On the Drawing Board, A 21st Century Curriculum", p. 63.

that exist as preparation for the few who aspire to careers in science and technology.[18]

Authors of a teaching text, Science and Society, offer a variety of ways to teach science predicated from the concern for continuous changes must take place in schools and society. Peterson, Bowyer, Butts, Bybee state:

> During the sixties and seventies, the trend in science education was to advocate a particular method of teaching science. This method was usually based on one or more theories about learning and development such as those proposed by Piaget, Bruner, and others. Inquiry and discovery learning dominated the scene.
>
> It is our view that books about teaching science need to introduce readers to a wide variety of approaches to teaching and communicating information about science rather than to advocate a single method or approach. In response to that need, we have provided a taxonomy of common teaching methods and created lessons and activities which illustrate how to use a variety of these methods.[19]

Science and Society (more of the STS approach) places emphasis on concepts as follows:

1) the impact of science on society
2) medical research
3) population growth

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[18]Association for Supervisor and Curriculum Development Curriculum Study Institute.

[19]Peterson, Bowyer, Butts, Bybee, Science and Society, Charles E. Merrill Publishing Co., Columbus, 1984, p. VI.

4) food shortages
5) energy
6) technology
7) exploration of space
8) science as a search for knowledge
9) the social context of science
10) the history of science education
11) object teaching
12) nature study movement
13) elementary science movement
14) interdependence of science and society
15) identity and organization of matter
16) change and interaction of matter
17) limitations of change
18) conservation of matter.[20]

The authors see the significance of science as the ultimate search for knowledge. However, the social context of science is intertwined within the multi-method approach. The authors of Science and Society state:

> As the world population grows, it will be important for all members of society to think of themselves as living within and functioning as a part of a global environmental system. Actions and personal decisions of every individual now affect the quality of our lives and our environment, the earth. If students are to understand the units of science, and the impact that people have upon each other and the environment, they will need to learn to think in new ways and try to understand the attitude and values of others in society.[21]

These authors emphasize that concepts in science are interrelated. Five key concepts for evolving

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[20]Ibid, p. 11.

[21]Ibid, p. 22.

science are identity, organization, interaction, change, and limits. These concepts are dynamic and essential for citizens of tomorrow to become aware of responsibility to seek the knowledge needed to make informed science-related decisions.

In a recent article on Qualitative Science, Penick and Yager quote students as stating: "Science classes make me unhappy."(Fifty-three percent of 17-year olds and fifty-seven percent of 13-year olds on 1981-82 National Assessment on Science). More emphatically, eighty-six percent of those same 17-year olds agreed that concepts or knowledge gained in science had nothing to do with the real world.

Penick and Yager disdain the quantitative science approach as decisively as students. Hence, they recommend the qualitative approach. These professors argue:

> Qualitative physical science programs emphasize experience with phenomena that includes designing, comparing, measuring, and analyzing. Students compare 'phenomena with statistics,

> graphs, and other mathematical techniques. Generally laboratory oriented, qualitative programs include long-range projects during which students must make decisions and deal with the consequences of their actions while engaging in real-world situations.[22]

Then development of creative science skills in teaching method as well as process skills promises the greatest payoff for individuals and for society. Both divergent production abilities and transformation abilities are important to creativity. Divergent production abilities make people more fluent or able to produce quantities of ideas while transformation abilities make people more flexible, which leads to unusual proliferation of novel ideas for which a quality index is more important. Guilford interviewed a number of creative scientists, engineers, and others and discovered these professionals rated transformation abilities higher than the divergent-production abilities.[23]

The creative process is the same in the arts as in the sciences. Science need not be approached in the positivist tradition. Approaching science from a

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[22]Penick, John E. and Yager, Robert "Qualitative Science, Quantitative Results", Educational Readings, Feb. 1985, p. 94.

[23]Educating the Ablest, F.E. Peacock Publishers, 1979, p. 23.

different angle may provide students with a better idea of what science is all about. Basic threads of continuity in science should include pattern, change, chance, and feedback. Judson, in his book, The Search for Solutions, demonstrates that the production of theories must be a dynamic process in which the human mind is really at play, developing all kinds of outlandish ideas. The interplay of ideas and theories is much more exciting to students than an endless bombardment of facts. It is essential for students to see that the value of a theory is not only just in its rightness or even primarily in its rightness, but in its ability to stimulate the mind. "Successful" theories are always tentative. They are simply the most excellent a limited mind can come up with at a given moment. We see this happening before our eyes in histories of theoretics. Change -- had we better not inculcate this into our curricula? For example, today Stephen Jay Gould (Harvard)

> contends that many ideas on evolution that are considered important today, including neutral selection, punctuated equilibrium, and selection among genes and species as well as among individuals, are not legitimate in terms of strict Darwinism. He isn't saying that Darwin's theory is dead, that it no longer has validity, but is must be modified, or as he puts it, expanded. Evolution is such an intrinsic part of

> of biology that it may be difficult for students to understand how such a powerful theory can be questioned unless they have been given some understanding of the tentative nature of theories. Powerful theories are those that are strongly predictive, that explain a great deal.[24]

Patrick N. Hunt deals with the problem solving approach to learning in his article, "Making Rounds with Dr. Semmelweis," in The Science Teacher.[25] He approaches science teaching by exposing his students to a few selected puzzles and paradoxes as exercises in problem solving. He utilizes Raymond Smillyan's puzzles, books by Martin Gardner and James Fixx, the games columns of Scientific American and Omni, Games magazine. An example of a problem is taken from an exercise developed by the medieval scholar Alcuin; it is as follows:

> A man must cross a river with an entourage of a fox, some fresh corn, and a goose. The boat is so small that he can only take one of them at a time. Because the animals are hungry, the man cannot leave the goose alone with the corn or the fox along with the goose. What is the least number of crossings the man can make to get the group safely (and still alive) to the other side.[26]

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[24]Maura C. Flannery, "Turning Teaching Around," The American Biology Teacher, vol. 44, No. 6, Sept. 1982, pp.370-371

[25]Patrick N. Hunt, "Making Rounds with Dr. Semmelweis," The Science Teacher, January 1984, pp. 33-37.

[26]Ibid.

Puzzles such as these stimulate the mind. They are most applicable to scientific reasoning when solved through graphs or networks.

Let M = Man, F = Fox, C = Corn, and G = Goose

MFCG (River Bank)	....	CF	MG	
			crossing	
		F	M	G
		F	MG	G
		F	MG	C
		F	MF	C
		G	M	FC
			MG	FC .. (River Bank) MFCG

This problem demonstrates a need for logic in scientific inquiry. Direct transference also is applicable with chemicals in a hypothetical relationship.

Hunt cites other stimulating processes such as having students describe his/her house in a deductive fashion (start with street address, move to floor plan of house, describing it in detail). He then reverses the process and utilizes the inductive method (start with the house, begin with a particular item, proceed

to locate the room in the house, give the address on the street, describe the street in relation to a section of the city or town, the town within a county, then within the state, region, country, planet, solar system, galaxy, universe, etc.).

Thirdly, Hunt advocates taking historical experiments and having his students analyze these. Examples and problems are given, then the students must reconstruct the hypothesis. Hunt uses simple but obscure experiments students may not have encountered. An example might be the Ignaz Semmelweis deductive experiment that washing hands and sterilizing the environment helped combat infection in the Allgemeines Krankenhaus in Vienna in 1843. From the Semmelweis experiment, Hunt shows that Semmelweis' supervisors and colleagues were not ready to accept this logic, and that not until three decades later could Lister and others persuade the medical community of the need for sterilization and sanitation in hospitals.[27]

We have made a smattering trace of science teaching approaches from the positivist tradition to more open ended and thought provoking approaches. We will close this chapter with a controversial yet much needed

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[27]Hunt, "Making Rounds with Dr. Semmelweis," pp. 35,36.

approach to science, that being the Bioethics from an Interdisciplinary Perspective. Singleton and Brock in their article, "Teaching Bioethics from an Interdisciplinary Perspective,"[28] expounded on the origins of bioethics as coming from biomedicine. These writers see bioethics as that amorphous area of knowledge between the science of biology on the one hand and the practice of medicine on the other. They state, "Whenever human values and sensitivities come into conflict with any science, perplexing problems may emerge. Since these problems involve values, feelings, sensitivities, and traditions, they are usually by definition moral or ethical problems, not exclusively scientific or technical ones."[29] These areas are thought provoking and deal not only with science buy a variety of different approaches. Singleton and Brock cite James Gustafson (1970) as categorizing bioethical issues into three sections being (1) scientific fact and scientific fiction (methods of scientist), (2) perspective from which we view the human situation (methods of historian), and (3) rights and values (methods of philosopher or theologian).[30] All of these

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[28]Rivers Singleton and Brock Heyward, "Teaching Bioethics from an Interdisciplinary Perspective," The American Biology Teacher, Vol. 44, No. 5, May 1982, pp. 280-285.

[29]Singleton and Brock, "Teaching Bioethics from an Interdisciplinary Perspective," p. 280.

[30]Ibid.

disciplines weave a web of interconnectedness, one move relying on another move for support and decisiveness. The one interesting aspect of the bioethical approach is that students begin to understand that there is no one ultimate correct answer. Different answers perhaps may be different for people in different situations or from different perspectives. The ultimate value of this approach lies in the fact that it helps inculcate an open minded attitude of give and take along with reason. Hopefully, when a student emerges from a bioethics course, he/she will be able to stand in another's moccasins and at least try to understand the other person's rights, choices, and positions. From this will come the highest, most prized form of ethical behavior, that of intrinsic control and values unframed by dogmatic dictums. As Socrates purports, "An unexamined life is not worth living." Let us as educators guide our students to a high plateau where each one might stand back to assess the life worth living.

CHAPTER IV
Recommendations

The question generated to this point of the discourse is "should not the total curriculum guide students to assess the life worth living?" The writer, in light of this statement, will now examine the most appropriate science curriculum for enhancing all learner's lives and inculcating a sense of appreciation as well as understanding of the pulsating Universe in which we all must exist.

John S. Rigden, in an enlightening article, "The Art of Great Science" states:

> The place of science in school and university curricula is jeopardized by this common view. Why require a subject that is taught merely as the logical manipulation of factual information? The legacy of such an educational experience is meager. Factual information is quickly forgotten and the student's logical faculty is left with nothing to manipulate.
>
> The role of science in contemporary society is misunderstood as a consequence of the common view. When science is seen as the regular, uninhibited advance of knowledge, the gravely serious problems building in our world come to be viewed cavalierly, because people assume that "science will solve them.

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[31]Rigden, Johns, "The Art of Great Science," Phi Delta Kappas, May, 1983, p. 616.

Science needs to be viewed as an endeavor that will complement our dynamic existence in this world. According to Webster's New Collegiate Dictionary, synergism is defined as the cooperative action of discrete agencies such that the total effect is greater than the sum of the two effects taken independently, as in the action of mixtures of certain drugs. Hence, to be truly effective, science must be viewed synergistically. The truly balanced education then for global knowledge must be based in knowledge, values, and skills. Learners should be presented with novel and humane approaches to science, that in which the web of lives is evident. Learners must be able to take classroom experiences into the real world and utilize skills and knowledge to enhance their own life.

NSTA Horizons Committee envision the following propositions for an appropriate 21st Century Curriculum:

1) Science is the persistent effort to explore the material universe and to create order by testable explanations of observed objects and events;

2) Applied science, the interface between science and society, is a necessary component of science education;

3) Effective science education should produce scientists and informed citizens prepared to deal responsibly with social issues related to science and technology;

4) We live in an age when learning about science is necessary for becoming an informed citizen;

5) People differ in their abilities, interests, and prior experiences. As a consequence, individuals learn at various rates and over the same period of time, reach different levels of accomplishment;

6) Teachers have been and will continue to be the single most important part of schooling and science education;

7) Students need teachers to guide and assist them as they begin and continue to learn Science, but the nature of this need changes as students and tasks change.[32]

These propositions propounded by the NSTA Horizons Committee establish the framework for a global and working science curriculum. Science as it exists today delves more into shades of gray as what certain values may predicate. Wherever human values and feelings move into conflict with any science on in-face issues, perplexing issues surface and often these issues are not exclusively scientific or technical ones. Science does involve the of-human existence, hence a broad

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[32]Fletcher Watson, "On the Drawing Board - A 21st Century Curriculum", The Science Teacher, March 1983, pp. 62-63.

variety of issues come under its heading. Enter the interdisciplinary method of teaching. The Center for Science and Culture at the University of Delaware, in the past several years, has utilized many interdisciplinary courses focused on bioethics and related problems. The particular courses include teams of savants from fields of Science, English, History, and Philosophy. Each team member contributes to a given issue shedding light on issues in different facets.

One course at the University of Delaware utilizes the interdisciplinary approach with bioethical issues. Subjects taught include the abortion controversy, genetic diseases, truth telling among physicians, fetal research, human experimentation, mental illness and others. The role here of the scientists is to present material as factually as possible. The philosopher would attempt to demonstrate how specific ethical principles in each issue are related to more basic philosophical principles. The savants of English and History would provide an exploration of how people experience the moral and ethical dimensions of their lives in a more dynamic and perceptive way then can be observed through sketchy singular case studies. Within

these parameters, each discipline complements the other and provides an integral part for checks and balances. Then each is free to point out the need for further clarification or expansion of appropriate issues. In this manner, each discipline will illuminate the problem at hand from its own particular perspectives. See Tables 1 and 2.

For a great many learners, secondary biology is their last formal exposure to science. The real world is not categorized into discrete disciplines; the real world is interdisciplinary.

Environmental issues involving land usage and management as well as wildlife must utilize consideration not only of the values of present society, but of values of future societies as well as to a consideration of the obligations of the present society to future societies. Interdisciplinary approaches to environmental education delve into a more humanistic view of education. Work of Abraham Maslow, Carl Rogers, Louis Raths, Gerald Weinstein, Sidney Simon, and others such as Rivers Singleton and D. Heyward Brock perpetuated the humanistic movement in education. The philosophy underlying the approach seems to have struck a chore within the souls

TABLE 1

SCHEDULE OF BIOETHICS WORKSHOP

DATE	DISCUSSION TOPIC
Preliminary Session	Euthanasia Literature Films Please Let Me Die Who Shall Survive?
Day 1	Introduction to Ethical Theory Abortion Film Session Rappaccini's Daughter Dr. Heidegger's Experiment Technology and Values: The New Genetics
Day 2	Literature Fetal Research (birth defects) Discussion of Case Studies
Day 3	Literature Introduction to genetic diseases (Joint Session) Genetic diseases Discussion of case studies
Day 4	Human experimentation Literature Discussion of case studies
Day 5	Introduction to the recombinant DNA debate (Joint) Recombinant DNA Ecology issues (Joint) Discussion of case studies
Day 6	Pedagogy and Implementation of Bioethical Concepts Summary

Source: The American Biology Teacher, Vol.49 No. 5 May 1982, p. 282.

TABLE 2

READING LIST FOR THE BIOETHICS WORKSHOP

GENERAL TEXT:

1A. Kieffer, G.H. (1979)	Bioethics: A Textbook of Issues Addison-Wesley Publishing Co., Menlo Park, California

Literary Works:

1B. Durrenmatt, F.	The Physicists
2B. Hawthorne, N.	Dr. Heidegger's Experiment
3B. Hawthorne, N.	Rappaccini's Daughter
4B. Hawthorne, N.	The Birthmark
5B. Huxley, A.	Brave New World
6B. Tolstoy, L.	The Death of Ivan Iiych

Bioethical Essays and Technical Papers:

1C. Anon (1975)	"The Commission Report: Deliberations and Conclusions" Hastings Center Report 5:41-46.
2C. Berg, R. (1979)	"Recombinant DNA Research Must and Can Be Done Safely" Trends in Biochemical Sciences, Editorial.
3C. Berg, P. and M. Singer (1976)	"Seeking Wisdom in Recombinant DNA Research "Federation Proceedings 35:2542-2543.
4C. Callahan, D.	The Meaning and Significance of Genetic Disease: Philosophical Perspectives (Reprinted in Beauchamp and Walters (1978). p. 581-585).
5C. Cohen, S.N. (1975)	"The Manipulation of Genes" Scientific American 233: 24-35.
6C. Cohen, S.N. (1977)	"R-combinant DNA: Fact and Fiction" Science 195: 654-657.
7C. Fletcher, S. (1975)	"Pragmatists and Doctrinaires" Hastings Center Report 5:36-37.
8C. Fletcher, S.	The Ethics of Genetic Control (Excerpted and reprinted in Beauchamp and Walters (1978). p. 585-587).
9C. Friedman, T. (1971)	"Prenatal Diagnosis of Genetic Diseases "Scientific American 255:34-42.

10C. Green, R.M. (1977) "Integenerational Distributive Justice and Environmental Responsibility" BioScience 27: 260-265.

11C. Kamisar, Y (1958) "Some Nonreligious Views Against Proposed 'Mercy-Killing' Legislation "Minnesota Law Review 43 (Reprinted in Beauchamp and Walters (1978), p. 308-317).

12C. Kant, I. Fundamental Principles of the Metaphysics of Morals (Excerpted from Gorovitz et al. (1976) p. 28-35.

13C. McCormick, R.A. (1975) "Fetal Research, Morality and Public Policy" Hastings Center Report 5:26-31.

14C. Mill, J.S. Utilitarianism (Excerpted from Gorovitz et al. (1976) p. 35-47.

15C. Noonan, J.T. An Almost Absolute Value in History (Reprinted in Feinberg (1973) p. 10-17).

16C. Scott, R.Jr. (1978) "Environmental Ethics and Obligations to Future Generations" in Obligations to Future Generations, R.I. Sikora & B. Barry (eds.) Temple University Press, Philadelphia.

17C. Sinshemer, R. (1976) "On Coupling Inquiry and Wisdom" Federation Proceedings 35:2540-2542.

18C. Tooley, M. A Defense of Abortion and Infanticide (Reprinted in Feinberg(1973)p.51-91).

19C. Various authors Readings on Informed Consent and Coercion (Excerpted from Gorovitz et al.(1976)p. 123-167).

20C. Wald, G.(1976) "The Case Against Genetic Engineering" The Sciences,Sept/Oct 76.p.6-12.

21C. Walters, L.(1975) "Fetal Research and the Ethical Issues" Hastings Center Report 5:13-18.

22C. Wasserstrom,R.(1975) "The Status of the Fetus" Hastings Center Report 5:18-20.

23C. Williams, G.(1958) "Mercy-Killing' Legislation - A Rejoinder" Minnesota Law Review 43 (Reprinted in Beauchamp and Walter (1978) p.318-323).

of people who want to maintain their humanity in the face of some depersonalizing conditions.

John Denver expounds:

> Each of us alive today shares a commitment to the continuing health of this planet. It is not just our home -- it is a home we share with all other living things.
>
> Our future depends on our working to maintain and improve the quality of the environment for life on this earth.[33]

With this philosophy, an interdisciplinary approach to environmental education is introduced. One fine example of interdisciplinary approaches to learning, Project WILD,is new on the scene of environmental education. Project WILD is an interdisciplinary, supplementary environmental and conservation education program emphasizing wildlife.

The Project WILD (Wildlife in Living Dimensions), approach is based on the premise that young people and their teachers have a vital interest in learning about the earth as home for people and wildlife. The program emphasizes wildlife -- because of its intrinsic, ecological, and other values, as well as its importance

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[33]Project Wild, Western Regional Environmental Education Council, 1983.

as a basis for understanding the fragile grounds upon which all life rests. Project WILD is designed to prepare young people for decisions affecting people, wildlife, and their shared home, earth. In the face of pressures of all kinds affecting the quality and sustainability of life on earth as we know it, Project WILD addresses the need for human beings to develop as responsible members of the ecosystem.[34]

There may not be a single pathway to meet life's current challenges. Hence, the curriculum must involve integrated critical thinking skills. The interdisciplinary approach to education certainly encompasses this. We as educators must equip students with the necessary intellectual skills to learn subject matter and critical thinking. The interdisciplinary approach more frequently incorporates strategy and reflective thinking skills than didactic approaches.

Nicherson reflects:

> Heuristic, as the word is used in the literature on problem solving, is roughly synonymous with strategy. A heuristic is an approach to a goal that is believed to have a good chance, but not certainty of

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[34]From Project WILD Manual, 1983.

> success. Typically, heuristics are used on problems that are sufficiently complex that analygorithmic approach -- a detailed step-by-step prescription that is certain to succeed is not possible.[35]

We as educators should desire to take our students to that higher pinnacle where decisions are made from an interplay of reflections of facets from many shining surfaces. Much of the interdisciplinary approach does focus on different levels of thinking. Utilizing these strategies requires teacher awareness and reflection. The writer sees a need for teachers to be aware of the approach to leading the learner to that higher level. The cognitive level matching approach has possible merit in enhancing heuristics.

The cognitive levels matching approach implemented at Shoreham-Wading River School refers to a teacher's ability to "use formal and informal means of assessing the cognitive levels of students and on the basis of this developmental perspective to adapt instruction according to those needs." This ability is contingent upon the teacher acquiring a "developmental perspective." The methods for acquiring this perspective suggest a

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[35]Ray S. Nicherson, "Kinds of Thinking Taught in Current Programs," Educational Leadership, Sept. 1984, p. 30.

fundamental change in instruction. The renewed emphasis on cognitive levels matching is the result of current interest in neurobiological research particularly that of Epstein, but cognitive levels matching (CLM) cannot directly test his hypothesis. The emphasis of CLM has thus become an emphasis on strategies to assit teachers to teach from a developmental point of view. Strategies are described which can assist teachers to teach "from the child's point-of-view and thus to begin the process of matching."[36]

Six levels are rounded estimates in stages of development of logical thinking: preparational, concrete operational thought, and formal operational thought. There are strengths and limitations in child thought which reinforce the basic Piagetian notion that child thought really is different in kind than adult thought. The child's point of view, the child's construction of knowledge is different from that of the teacher. The six cognitive levels are placed parallel to their corresponding stage. For each levels, there is a brief description of the type of problem solving strategy that is characteristic of the level. Level IA is often cited

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[36]Patricia K. Arlin, "Cognitive Levels Matching: An Instructional Model and A Model of Teacher Change," Journal of Children in Contemporary Society, p. 2.

as Early Preoperational and Level IIIB, High Formal. At this point the CLM and Epstein's approach appear to diverge. It is the writer's opinion that although CLM provides a ground work for approaching teaching, it appears rigid. No student will be at the same exact level in all aspects of thinking as the next student. CLM projects have become systematic efforts to assist teachers in acquiring a 'developmental perspective', in adapting instruction to the cognitive levels of students through such adaptations.

Developing teacher strategies is what CLM and other curricular development projects are about. These strategies become the bridge between theory and practice. Both the knowledge base and the strategies gradually assist the teacher to accommodate a developmental perspective. Reflective practice is encouraged in developing appropriate strategies. To have a developmental perspective is to consider curriculum and instruction in general, and the minute-by-minute interactions with children in particular from "the child's point-of-view." However, the danger lies in adhering too rigidly to such stages and "judging" a child inappropriately. It is this writer's opinion that under such a watchful eye any "intelligently sensitive" child will feel the

invisible restraints and judgments from teachers. Although we hear cries for more rigidity to basics from proponents of "A National At Risk," etc., if we cannot allow a child eventually to "be", at least with a good portion of the talented, we run risks of rebellion. An example of such curricular approach lies in the following example of an "Analysis of the Cognitive Levels of the Topic: Photosynthesis," p. 1, 2, 3, 7 (analysis of activities), and 8, by Marh Lou Abata and Elaine Boyrer, Cognitive Level Matching, July 10, 1981.

Photosynthesis is a required topic in the New York Regents' High School Biology curriculum. As defined in the Regents' Curriculum Outline, photosynthesis is the process by which light energy is trapped by chlorophyll and converted into the chemical bond energy of simple sugar molecules. It is an inherently abstract subject, the understanding of which requires formal thinking skills. Students must have some understanding of the physics of light, chemical structure and reactions, the process of diffusion, and the biochemical basis or organismic activities, to understand photo-synthesis. Most of the prerequisite subject matter is also abstract and requires formal cognitive ability on

the part of students.

The textual reading materials contain many terms which are abstract and also require formal cognition. The texts presuppose student understanding of all subtopics mentioned above as necessary to an understanding of photosynthesis.

Activities are suggested by the Regents' curriculum but can be designed by individual teachers as they see fit, to illustrate or demonstrate photosynthetic concepts. We have designed activities, where possible, as concrete proof or illustration of the concept to be mastered. However, in many cases, comprehending the meaning or significance of the activity itself requires logical and formal reasoning.

Reading Material

Texts used in teaching and in analyzing this topic are:

1. Biological Sciences Curriculum Study, Biological Science -- An Inquiry Into Life, 3rd ed., Harcourt, Brace, Jovanovich, Inc., N.Y., 1973.

2. Biological Sciences Curriculum Study, Biological Science -- A Molecular Approach, 4th ed., D.C. Heath and Co., Lexington, Mass., 1980.

3. Kraus, David, Concepts in Modern Biology, Cambridge Book Co., N.Y., 1974.

4. Mehrens, William A., and Irvin J. Lehmann, Measurement and Evaluation In Education and Psychology, Holt, Rhinehart and Winston, Inc., N.Y., 1973.

5. The University of the State of New York, Bureau of Secondary Curriculum Development, Biology -- A Syllabus For Secondary Schools, The State Education Dept., Albany N.Y., 1968.

Analysis of Reading Material

Concrete and abstract words and phrases which occur in the books used in teaching the topic of photosynthesis include the following:

Books and Pages	Concrete	Abstract-Formal
Concepts in Modern Biology, p. 222-229	We find	When man obtains useful energy by burning . . . he is using the sun's energy which was trapped long ago during photo - synthesis
	Divide	
	Expose	Knowing that the sugar . . . is changed to starch, we conclude that light is needed. . . to carry on photo-synthesis
		Control
		We, therefore, conclude
		If, the experiment is continued . . . Why?
		Dissolved
		Law of Conservation of Matter
		Carbon fixation
		"Tracer"

Books and Pages	Concrete	Abstract-Formal
	Granum consists of layers of membranes stacked . . . like a pile of coins	Color of an object depends upon the wavelength that it reflects or transmits
Biological Science -- A Molecular Approach p. 115-121		Dilute
		The 1st organisms to use sunlight would probably have acted partly as heterotrophs .. and as autotrophs
	They contain chlorophyll	They can use the energy from the absorbed sunlight to make new cellular materials from organic compounds
	Photo, Light	The purple pigment absorbs light energy that is used to make ATP
	Synthesis -- putting together	Suggests
		Ratio
		If, however . . . then
		Restorative, despite, assured, quantitative
		Gas exchanger
		Deriving
		Resulted in . . .
		The process of photosynthesis is thus the key to the formation of all organic compounds by plants

Books and Pages	Concrete	Abstract-Formal
Biological Science -- An Inquiry into Life, p. 351-361		Related
		Appreciate the relationship between structure and function
		How might the location . . . be advantageous in light absorption?
		On the basis of structure, what sorts of function might they have?
		In what indirect way might the cutin affect the efficiency of photosynthesis?
		From appearance only, what function can you deduce . . .
		Form a hypothesis
		What can you conclude about the solubility . . .
	Observe	What is the significance of this observation?
	Crush	On the basis of your data, interpret . . .
		Guard cell mechanisms
		Water balance changes
		Ion distribution

Analysis of Activities

Key to symbols used for Piagetian classification:

EC = early concrete C = concrete LC = late concrete

EF = early formal F = formal LF = late formal

Objective			
ACTIVITY A -- SHINE LIGHT THROUGH A PRISM			
1. The student will see that white light is altered to form a band of different colors.	1. What colors of light are seen on the other side of the prism from the light source?	EC	Knowledge
2. The student will state that the prism has an effect on the light.	2. What would occur if the prism or the light were rotated?	F	Application
3. The student will hypothesize that white light consists of a band of colored light.	3. Explain the relationship between white light and the band of colored light.	F	Analysis
ACTIVITY B -- VIEW CHLOROPLASTS IN ELODEA LEAVES UNDER THE MICROSCOPE			
1. The student will see green chloroplasts as discrete structures	1. What color are the chloroplasts?	EC	Knowledge
	1a. How many chloroplasts are in each cell?	C	Knowledge
2. The student will say that chloroplasts are part of plant cells.		C	Comprehension

Objective	Questions Students Are Asked	Piagetian Level	Bloom Classification
ACTIVITY C--EXPOSE A SOLUTION OF CHLOROPHYLL EXTRACT TO LIGHT			
1. The student will see that white light does not appear on the opposite side of the chlorophyll from the light source.		EC	Knowledge
2. The student will see that green light appears on the opposite side.	2. What color of light do you see on the opposite side of the container?	EC	Knowledge
3. The student will infer that chlorophyll affects the light.	3. Why is green light seen on the opposite side?	LC/EF	Comprehension
4. The student will hypothesize that all colors of light but green are absorbed by chlorophyll, and that green light is reflected.	4. Explain how chlorophyll alters white light.	F	Analysis

CHAPTER V
Summary

This discourse has addressed the problems of science education. The writer purported the lack of preparation students receive for citizenry of the future as related to the sciences. Students are not being prepared through academic courses to make ethical decisions in life. Most decisions involve aspects of science and interrelated fields. If we are to survive in the complex technological society that is already upon us, science must make a strong comeback. Robert B. Sigda in an article, "The Crisis in Science Edudation and the Realities of Science Teaching in the Classroom" states that: "Successful science teaching today is a complex interaction of students and teachers with the program, classroom, home, and local and national communities."[37]

Today's science, as we have seen, delves little into the true synergistic approach of the interdisciplinary science methods. We have seen a need then for science teaching that will interact with the new technologies we face.

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[37]Sigda, Robert B. "The Crisis in Science Education and the Realities of Science Teaching in the Classroom", Phi Delta Kappas, May 1983.

Courses of the 60's and 70's were briefly reviewed. The CBA, CHEMS, BSCS, ISSC, ESCP approaches were more shotgun-type attempts to process skills. Little reflective thinking or higher level thinking was provided for in these programs. The FUSE program provided a modular unit approach to science which centers around a theme with a variety of projects and learning activities. Other approaches were more shotgun-type attempts to process skills. All have merit in that they advocate a more progressive hands-on attitude to science.

All science though must not neglect the creative processes. Problem solving complements science teaching. Teachers must advocate logic in scientific inquiry as well as analogy or transference. Bioethics utilize higher levels of thinking as well as skill applicability.

Recommendations for science of the future include interdisciplinary approaches to learning science and dealing with current societal problems. Relevant to today's education is the holistic view which addresses the affective domain as well as the intellectual. Strategies in problem solving have merit in that students will see a variety of methods to solve a singular problem. Also, viewing the learner from a developmental approach clarifies teacher expectations. The Cognitive Levels

Matching Program takes students from early preoperational thinking to high formal type thinking when possible. With the CLM program teacher strategies are essential. Teachers must be able to assess student needs and developmental stages. Most of this is accomplished through direct observation and assessment by dealing specific problems.

The writer has now examined a variety of curriculum approaches as well as techniques entailed in some. Recommendations for the future science curriculum lie in the multidisciplinary and interdisciplinary fields. Educators must be able to handle these approaches thoroughly and efficiently. Thus enters the Cognitive Level Matching Program. We then, in science, will take our students to a higher plateau of learning and enhance a life worth living.

In the previous chapter, the writer has delineated a plan of action for science education. Curriculum leaders in secondary science must be committed, daring, and imaginative to move forward with this fast paced world. The study of science must not be elective. The sciences and mathematics must have their rightful place in the school curriculum as basic requirements, a part of the core curriculum from kindergarten through grade

14. A vertically articulated and interdisciplinary science curriculum must be stressed. Secondary science should be oriented around issues rather than subjects, with multidisciplinary facets complementing the issues. As time progresses and implementation is monitored, new instructional materials may be required such as those included in the Project WILD manual. Teachers must demand appropriate training and instructional materials and facilities. Pilot test programs such as university and environmental awareness programs being implemented in many states must be assessed. Revision and/or development of instructional materials must be an ongoing process as necessary.

For the secondary science curriculum, the writer proposes at this time a modified interdisciplinary system in which each discipline retains an alloted amount of time to knowledge dynamically progressing to problem and issues interrelated to other areas. Teachers must include the goals espoused in project synthesis. Those being 1) personal needs, 2) societal needs, 3) academic preparation and 4) career education/awareness.

Volk states in "Project Synthesis and Environmental Education":

> Since science is inquiry-oriented, it should come as no surprise that there is considerable concurrence between the goals of science education and environmental education at the Issue Investigation and Evaluation Level. In describing the desired state of scientific inquiry processes and the nature of scientific inquiry, the project synthesis identified three main themes: science process skills, general inquiry processes, and the nature of scientific inquiry. While each of these three themes is germane to issue investigation and evaluation, probably the most cogent is the general inquiry theme. The general inquiry processes as described by the Project Synthesis Staff include "strategies such as problem solving, uses of evidence, logical and analogical reasoning, clarification of values, decision making, and safeguards and customs of inquiry.[38]

The writer proposes that science teachers reassess skills they teach in the classroom and encourage students as the Taoist helper to be aware of the role of professional scientists but be prepared to become world citizens of tomorrow.

APPENDIX

You are Ignaz Semmelweis, the young chief obstetrician of one of the best teaching hospitals of its time, the Allgemeines Krankenhaus, in Vienna, Austria, in 1843. Each day, at least one out of every six women in your maternity ward will become sick and probably die within a short time. This will continue unless you make a startling observation and implement an unusual, but easy, experiment.

You have the following facts in hand:

The hospital wards include the following: surgery, traumatic accidents, maternity, intensive care, psychiatric care, and infectious disease.

When maternity and other patients die, their bodies are placed in the autopsy room of the morgue in preparation for tomorrow's teaching lesson.

In the morning, doctors and medical students register individually for class and then proceed to the autopsy room.

Autopsies are done to determine the probable cause of death of each person.

The doctors and students leave the morgue as a group. After they change their soiled lab coats for fresh ones, they start the day's examination tour, beginning in the maternity ward.

They perform thorough pelvic examinations of some of the women. After changing their lab coats again, they move on to the ward for traumatic accident patients.

Each day students and doctors make rounds through the entire hospital.

During one day, 11 out of 12 of your maternity patients suddenly begin to run high fevers.

That night more of your patients become so sick that they must be removed from the ward. By the third night most of the affected patients are dead; their bodies have been wheeled to the autopsy room for the next day's lesson.

Fresh lab coats are already laid out for tomorrow's lesson.

You are depressed and tired. Suddenly, a thought hits you with the force of lightning!

What will you do to resolve the problem? Set up an experiment with a single variable and control factors.

What is your hypothesis?

Source: Patrick N. Hunt, "Making Rounds with Dr. Semmelweis", The Science Teacher, January 1984.

Name of person and experiment	Hypothesis	Single variable	Control	Conclusion
	(all columns cannot be fillled in for every experiment)			
Redi				
Needham				
Jenner				
Van Helmont				
Spallanzani				

Source: Patrick N. Hunt, "Making Rounds with Dr. Semmelweis", The Science Teacher, January 1984.

The Problem of Gierer and Schramm

You are Alfred Gierer, a biochemist. With your research partner, Gerhard Schramm, you are investigating the genetic nature of the tobacco mosaic virus (TMV). You make some observations and set up an experiment to test your hypothesis. You have the following information:

- You have a suspension of tobacco mosaic virus.

- You centrifuge the TMV suspension, identifying RNA and protein, among other substances, in the separation.

- You isolate the RNA and protein into two separate groups, both of which contain an identical ratio and volume of RNA and protein together.

- In the one group you separate the RNA from the protein by treating the mixture with phenol until less than 0.02 percent of the protein remains.

- In the other group you isolate the protein from the RNA by treating the mixture with dilute NaOH, leaving only protein.

- By exposing the two groups to live tobacco plants, you determine that the group containing only protein cannot reinfect the plants, while the group containing almost totally RNA can reinfect with TMV. (Later you show the presence of the protein, however significant or insignificant, to be nonessential.)

What can you infer from this data? Set up two groups by developing the contrasts between the groups mentioned. If possible, diagram the two groups. Is it likely that your hypothesis was validated as a conclusion? State the conclusion.

NOTE: If your students get snagged, have them construct the following graph. Start them with some data, but leave the rest for them to fill in:

Group	I	II
Substance	RNA and Protein + 0	RNA and Protein 0 +
Percentage (after treatment)	99.98 0.02	0 100.00
Result	TMV infection	no TMV infection

Source: Patrick N. Hunt, "Making Rounds with Dr. Semmelweis", The Science Teacher, January 1984.

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